Automatic Detection of Exudates in Retinal Fundus Images using Differential Morphological Profile

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Abstract— **This paper presents an automatic method for exudate detection from colour fundus images based on Differential Morphological Profile (DMP).The detection of exudates is important for the identification of eye diseases such as diabetic retinopathy. The method involves of three main phases. In the first phase, pre processing tasks like Gaussian smoothing and contrast enhancement is done. In the second phase, DMP is applied on the pre-processed image. The image obtained from DMP contains highlighted bright regions consisting of exudates and optic disc. In the next phase, feature extraction based on location of optic disc, shape index and area is done to obtain actual exudates. The performance of the proposed method is evaluated by applying it on the DIARETDB1 database. The specificity, sensitivity and PPV of the proposed method were compared with two other methods. The results show that the proposed method gives better results than the other conventional methods.**

Keyword- DMP, Exudates, Optic disc, retinopathy

I. INTRODUCTION

Diabetes is a common disease, in which the pancreas do not secrete proper amount of insulin in the body. Insulin is important for controlling the blood sugar level, thus humans affected with diabetes have high blood sugar levels .Patients suffering from this disease over a long period of time , get affected by a disease as diabetic retinopathy (DR) which attacks the retina .DR affects the blood vessels in the retina. It is a leading cause for various eye diseases and may even lead to blindness [1]. There are three phases of diabetic retinopathy, these are: i) non-proliferate diabetic retinopathy (NPDR) (ii) proliferate diabetic retinopathy (PDR) (iii) maculopathy [2,5].The mildest phase of DR is NPDR, in this phase, small blood vessels within the retina leak fluid or blood . The leaking fluid causes the retina to swell, developing small dot like deposits known as microanuerysms and hemorrhages [3].The next phase is PDR , in which new vessel grow on the inner surface of the retina leading to visual impairment [4]. Macula is an important part of human eye, it provides the central vision. In Diabetic Maculopathy, the macula is damaged by the fluid or protein leaked by the blood vessels [5]. The leakages cause the retina to harden and exudates (deposits of fat from the blood) occur near or on the macula [6]. Fig.1 shows the different components present in the retina these are: macula the central portion of the retina , fovea the central part of macula , optic disc (OD) , exudates and blood vessels [7].

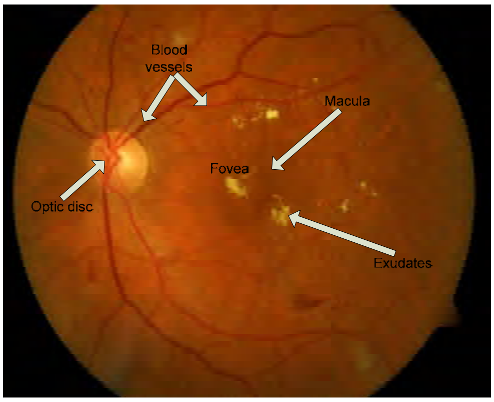

Fig.1 Main components of the human retina

Medical imaging has gained much popularity for computer assisted diagnosis of various diseases. In case of diabetic retinopathy Angiogram is acquired by specialists in ophthalmology clinics, and is marginally invasive, presenting a certain risk of side effects to the patient. Thus, image processing techniques are being widely used for detecting automatic diagnosis of DR from retinal images. A technique for exudate detection uses filter banks to identify candidate exudates and applies Bayesian classifier on these candidates to identify actual exudates [4]. Inverse surface thresholding utilizes FCM clustering , edge detection and otsu thresholding to distinguish exudates from the retinal fundus image and finally performs inverse surface thresholding to identify exudates [8]. Exudate detection based on adaptive thresholding and image partitioning , segments the image and then applies morphological operations to identify exudates [9]. A method based on Marker-controlled watershed segmentation is used for automatic detection of exudates [10].

A morphology based method uses the green layer of the retinal image and performs different morphological operators alongwith watershed transformation for exudate detection [11]. An ensemble-based method combines preprocessing and extractor techniques and uses a voting system to identify exudates[12].A active contour based model employs morphological operator and active contour based technique to identify candidate exudates on retinal images. The false detections are filtered by Naïve Bayes classifier [13]. A curvelet-based algorithm works on Fisher's linear discriminant analysis and color information to identify exudates and optical disc [14].OpticDisk is localized by backtracking the vessels to their origin. This is certainly one of the safest ways to localize the OpticDisk, but it depends on the backtracking of vessels [15]. In this paper, a method for automatic exudate detection is proposed. The proposed method is based on differential morphological profile (DMP).Bright regions in the preprocessed image are highlighted using DMP. The highlighted regions correspond to candidate exudates which include optic disc also. Optic disc is detected using Gaussian smoothing .Filtering of the candidate exudates is done using the information about the optic disk, shape index and area to obtain the final exudates. The proposed method was tested on DIRETDB1 database, the results obtained were quite satisfactory.

II. PROPOSED WORK

The flow chart of the proposed method for automatic exudate detection is shown in fig.2. The proposed method consists of the following steps :

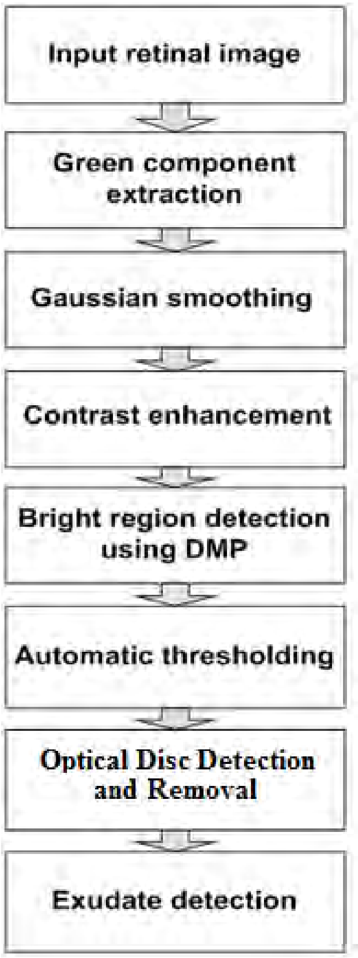

Fig.2 Flowchart of the proposed method

A. Input Retinal Image

The proposed method is tested on DIARETDB1 databases of retinal images available on the Internet [16]. DIARETDB1 is a Finish database consisting of 89 color fundus images of size 1500× 1152 pixels, captured using a 50^0 field-of-view digital fundus camera. DIARETDB1database contains a variety of retina images showing diabetic signs.

B. Green Component Extraction

The fundus image is a color image containing three different bands; red, green and blue. It is observed that the red and blue bands do not have significant information for exudates detection and thus it is sufficient to use the green band only. The input retinal image is a three layer image containing red, green and blue layers.

$$I = [I_R \quad I_G \quad I_B] \qquad (1)$$

Where I is the input RGB image. I_R, I_G and I_B represents the red , green and blue layers respectively. In the green layer, I_G ,exudates appear brightest as compared to the other two layers thus the green layer is chosen for exudates detection . The optic disc also appears bright but in the green layer it appears fragmented due to the high contrast of the blood vessels. Thus the optic disc can be easily removed.

C. Gaussian Smoothing

The Gaussian Smoothing Operator performs a weighted average of neighboring pixels based on the Gaussian distribution. This operator eliminates the effect of noise and other illumination effects. Thus the Gaussian low pass filter is applied on I_G using eq. (2), a pre-processing step in this method to enhance the quality of the input retinal image

$$I_S(x,y) = I_G(x,y) * g(x,y) \qquad (2)$$

Where * denotes convolution and g(x,y) is a Gaussian function represented by

$$g(x,y) = \frac{1}{2\pi\sigma^2} e^{\left(-\frac{x^2+y^2}{2\sigma^2}\right)} \qquad (3)$$

Where σ is the standard deviation.

D. Contrast Enhancement

The uneven illumination causes non uniform illumination in different parts of the image. Contrast enhancement is done to obtain uniform illumination and increase the contrast of exudates. A Equalization algorithm is applied to obtain the enhanced image using eq(4)

$$I_E = 255 \frac{I_S - I_{s,max}}{I_{s,max} - I_{s,min}} \qquad (4)$$

Where I_E is the enhanced image,I_S is the smoothed image, $I_{s,max}$ and $I_{s,min}$ are the maximum and minimum pixel value of the image I_S.

E. Candidate Exudate detection using DMP

DMP is a multi-scale image processing algorithm. It consists the combination of morphological operators such as the opening and closing by reconstruction with varying structuring element(SE) sizes and the derivatives of the resulting profile[17]. In this method, we use DMP by opening to highlight the exudates. The algorithm of DMP is as follows:

The opening profile Z_{γ_i} of the image I_E is defined as

$$Z_{\gamma_i} = I_E \varphi \ \delta_i \ , \qquad \forall\, i \in [0,n] \qquad (5)$$

where φ is the opening by reconstruction operator and δ_i is the structuring element.

$$\delta_i = \delta_{i-1} + \Delta \qquad (6)$$

where Δ is the step size by which the structuring element size is increased.
The derivative of the opening profile I_{DMP} is defined as

$$I_{DMP} = \left|Z_{\gamma_i} - Z_{\gamma_{i-1}}\right|, \forall\, i \in [1,n] \qquad (7)$$

The image obtained after applying DMP, I_{DMP} ,contains bright regions highlighted. Thus the highlighted regions in I_{DMP} are identified as candidate exudates. The image obtained from DMP is converted into a binary image by automatic thresholding. The binary image I_{CND} obtained after thresholding shows candidate exudates as foreground while all other pixels are made background

$$I_{CND}(x,y) = \begin{cases} 1 & I_{DMP}(x,y) \geq T \\ 0 & I_{DMP}(x,y) < T \end{cases} \quad (8)$$

Where T is the threshold obtained by OTSU algorithm [18].

F. Optical Disc Detection and Removal

The image obtained in the previous step contains candidate exudates some of which may be false detection. Therefore to eliminate the false detection feature extraction is done. Filtering of the detected exudates is an important task. This step will remove the false detections and the true exudates will be identified. For identifying the hypothesized connected components as exudates. Due to similarity in spectral properties features OD is also detected as exudates. Thus, an important step is to identify the pixels corresponding to optical disk. Optical disk can be differentiated from exudates by considering the shape and size of the disk. Optical disk is circular in shape and is bigger in size as compared to exudate regions. The image I_E was smoothed using a Gaussian filter of size 131×131 and was then thresholded to obtain a binary image with optical disk region highlighted. The OD was removed using Shape Index (SI) and Area. SI is the ratio of the area of a candidate exudate over the square of its boundary length. It varies from 0 to 1.It is observed that optic disc have circular shape. Thus, the value of SI for optic disc approaches to 1.This characteristic can be used to filter the optic disc.

$$SI(I_{CND}) = 4\pi \frac{Area(I_{CND})}{Perimeter(I_{CND})^2} \quad (9)$$

where $Area(I_{CND}) = \iint dxdy$ and $x, y \in I_{CND}$.

The area of each region is calculated by counting the number of pixels in the region. Large objects like optic disc whose area is larger than a predefined area are removed.

G. Exudates Detection

The exudates candidates that pass the above tests, i.e., shape index and area are identified as exudates. Those exudates candidates are integrated together using the logical “OR” operator to obtain the actual exudates. Thus,

$$I_{exudates} = \cup_{k=1}^{n} I_{cnd,k} \quad (10)$$

where ***n*** is the number of exudates candidates that pass the above tests, $I_{cnd,k}$ is the k_{th} exudates candidate and $I_{exudates}$ containing all the exudates.

III. RESULTS AND DISCUSSIONS

All The proposed method was implemented in MatlabR2009a. The value of different parameters used in the experiment are $\delta_i = 1$, $\Delta = 7$ and $n = 4$. The original colored retinal image is shown in fig3. The results of the various steps are shown in fig. 4(a)-(e).

Fig.3 Original Retinal Image

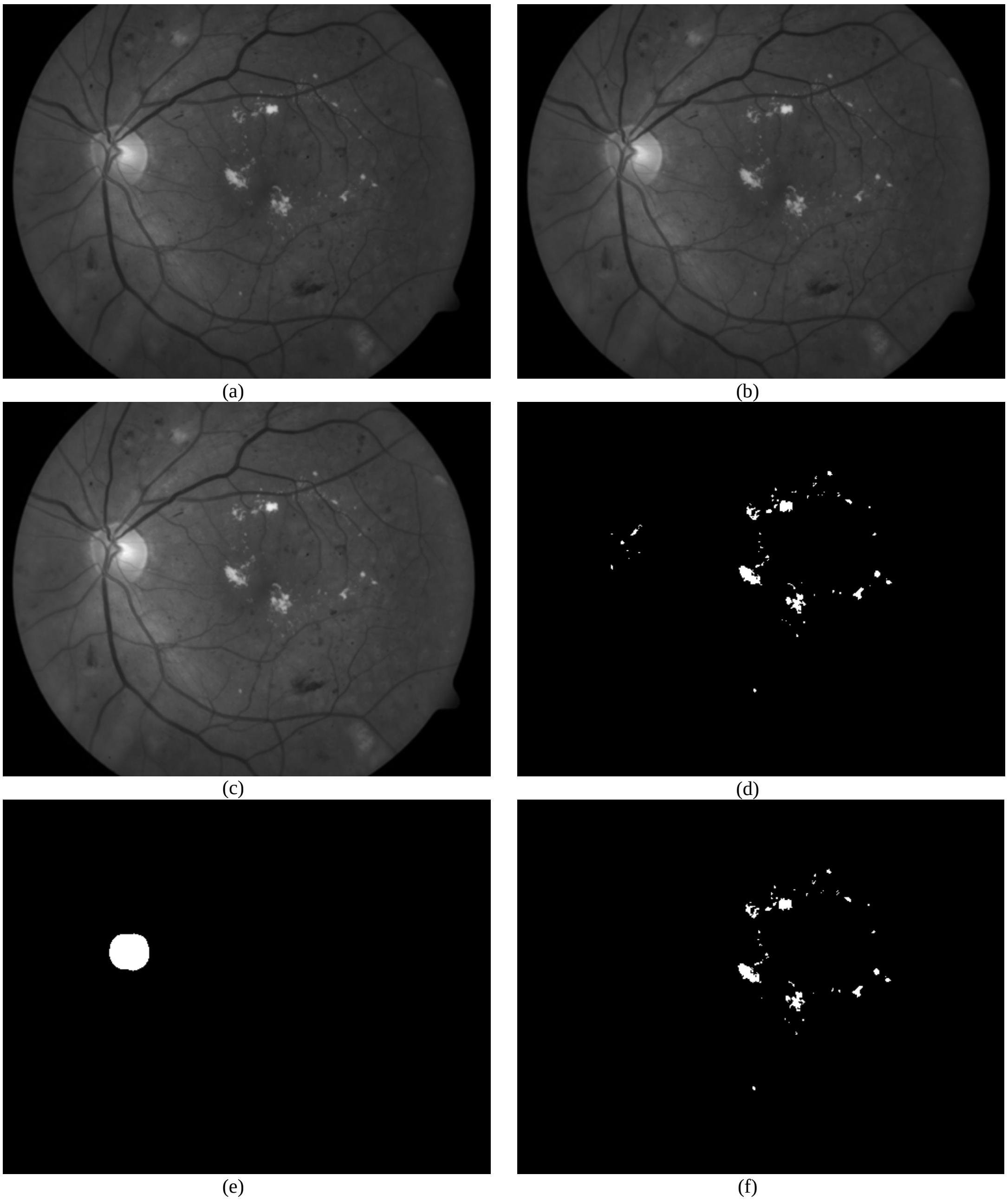

Fig.4 Result of various steps of the proposed method (a) Green Component (b) Gaussian Smoothing (c) Contrast Enhancement (d) Candidate exudates using DMP (e) OD Detection (f) Exudates detection

The quantative analysis was done using 89 images of DIARETDB1 [16] and the results were compared with two other methods. The performance was evaluated using the following parameters

1) True Positive(T_P): it is defined as the number of exudates correctly identified as exudates.
2) True Negative(T_N): it is defined as the number of non-exudates correctly identified as non-exudates.
3) False Negative(F_N): it is defined as the number of exudates identified as non-exudates.
4) False Positive(F_P): it is defined as the number of non-exudates identified as exudates

Based on the above mentioned parameters, four metrics sensitivity, specificity, Positive Predictive Value (PPV) and accuracy. Specificity is the percentage of non-exudate pixels that are correctly classified as non-exudate pixels. Sensitivity is the percentage of the actual exudate pixels that are detected .The positive predictive value (PPV) gives the proportion of identified exudate pixels which are true exudate pixels [19]. From these quantities, the sensitivity, specificity and PPV are computed using Equation 11, 12 and 13 respectively. These metrics are as follows:

$$sensitivity = \frac{T_P}{T_P + F_N} \qquad (11)$$

$$specificity = \frac{T_N}{T_N + F_P} \qquad (12)$$

$$PPV = \frac{T_P}{T_P + F_P} \qquad (13)$$

The quantative results of all the methods are summarized in table I.

Table I: Quantative result of the various methods.

Method	Sensitivity	Specificity	PPV
Walter et al[15]	96.45	99.93	87.70
Akram and Khan[3]	97.04	99.96	92.70
Proposed Method	97.63	99.99	98.23

It is observed that the proposed method detects exudates most accurately as its sensitivity is highest. The specificity and PPV values are 99.99% and 98.23% respectively which is higher than the other two methods.

IV. CONCLUSION

This paper presents, a method for automatic exudate detection based on DMP. The proposed method performs certain preprocessing steps on the green channel of the input image to enhance image quality. The exudate regions are highlighted using differential morphological profile. Optic disc is also highlighted along with exudates. The location of optic disc is identified using Gaussian smoothing. Filtering of the candidate exudates is performed using optic disc location. Two other parameters shape index and area are used for removing false detections. The performance of the proposed method was evaluated using DIARETDB1 database both quantatively and quantatively. The results confirm that the proposed method detects exudates quite efficiently and accurately. The comparison with other state of the art methods shows that the proposed method outperforms the other two methods.

REFERENCES

[1] A. Osareh, B. Shadgar and R. Markham, " A computational-intelligence-based approach for detection of exudates in diabetic retinopathy images," *Information Technology in Biomedicine, IEEE Transactions on*, vol. 13, no.4,pp. 535-545,2009

[2] S. Poddar, B. K Jha and C. Chakraborty, "Quantitative clinical marker extraction from colour fundus images for non-proliferative Diabetic Retinopathy grading," In Proc. IEEE International Conference on Image Information Processing (ICIIP), November,2011 ,pp. 1-6.

[3] U. M Akram, and S. A. Khan, "Automated detection of dark and bright lesions in retinal images for early detection of diabetic retinopathy," Journal of medical systems, Vol. 36, no. 5, pp. 3151-3162, October 2012.

[4] M. U. Akram, A. Tariq , M. A. Anjum and M. Y. Javed, "Automated detection of exudates in colored retinal images for diagnosis of diabetic retinopathy," Applied Optics, Vol. 51, no. 20, pp. 4858-4866,2012.

[5] D. Vallabha, , R. Dorairaj, K. Namuduri, and H.Thompson, " Automated detection and classification of vascular abnormalities in diabetic retinopathy,"In Proc. IEEE Signals, Systems and Computers. Conference Record of the Thirty-Eighth Asilomar ,Vol. 2,2004, pp. 1625-1629.

[6] A. Tariq., M. U. Akram, A. Shaukat, and S. A. Khan,"Automated Detection and Grading of Diabetic Maculopathy in Digital Retinal Images,"Journal of Digital Imaging, pp. 1-10, 2013.

[7] A. F. Amos, D. J. McCarty and P. Zimmet."The rising global burden of diabetes and its complications: estimates and projections to the year 2010,".Diabetic medicine, Vol. 14,no. S5,pp. S7-S85, 1997.

[8] H. Yazid, , H. Arof, and H. M. Isa, "Automated identification of exudates and optic disc based on inverse surface thresholding," Journal of medical systems, Vol. 36,no. 3,pp. 1-8,2012.

[9] H. F Jaafar, A. K. Nandi and W. Al-Nuaimy, "Detection of exudates in retinal images using a pure splitting technique," In Proc. IEEE Engineering in Medicine and Biology Society (EMBC), Annual International Conference of the IEEE ,2010,pp. 6745-6748.

[10] A. W. Reza, C. Eswaran, and K. Dimyati," Diagnosis of diabetic retinopathy: automatic extraction of optic disc and exudates from retinal images using marker-controlled watershed transformation," Journal of medical systems, Vol. 35,no. 6,pp. 1491-1501,2011.

[11] A. W. Reza, C. Eswaran and S. Hati, " Automatic tracing of optic disc and exudates from color fundus images using fixed and variable thresholds,"Journal of medical systems, Vol. 33,no. 1, pp.73-80, 2009.

[12] B. Nagy, B. Antal, B. Harangi and A. Hajdu," Ensemble-based exudate detection in color fundus images,"In Proc. IEEE Image and Signal Processing and Analysis (ISPA), 7th International Symposium, September 2011, pp. 700-703.

[13] B. Harangi, I. Lazar, and A. Hajdu, "Automatic exudate detection using active contour model and regionwise classification," In Proc. IEEE Engineering in Medicine and Biology Society (EMBC), 2012 Annual International Conference, August 2012,pp. 5951-5954.

[14] M. Esmaeili, H. Rabbani, A. M. Dehnavi and A. Dehghani, "Automatic detection of exudates and optic disk in retinal images using curvelet transform,"IET Image Processing, Vol. 6, no. 7,pp. 1005-1013,2012.

[15] T.Walter, J.-C.Klein, P. Massin, and A. Erginay, "A contribution of image processing to the diagnosis of diabetic retinopathy-detection of exudates in color fundus images of the human retina". IEEE Trans. Med. Imag. vol .21, no.10 ,pp1236–1243,2002

[16] T. Kauppi, V. Kalesnykiene and J.K. Kamarainen, et al. "DIARETDB1 diabetic retinopathy database and evaluation protocol,". Technical Report, Faculty of Medicine, University of Kuopio, Finland, 2007

[17] M. Pesaresi and J. A. Benediktsson, "A new approach for the morphological segmentation of high-resolution satellite imagery," IEEE Trans. Geosci. Remote Sensing, vol. 39, no. 2, pp. 309–320, 2001.

[18] N. Otsu,"A threshold selection method from gray level histograms," IEEE Trans. Syst., Man, Cybern, Vol. 9,no. 1,pp. 62-69,1979.

[19] M. M Fraz,., A. Basit, and S. A. Barman, "Application of morphological bit planes in retinal blood vessel extraction," Journal of Digital Imaging,vol.26,no 2, pp274-286,April 2013.